MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CLARK UNIVERSITY

COMMUNICATED BY EDMUND C. SANFORD

XXI. A PRELIMINARY REPORT OF EXPERIMENTS ON TIME RELATIONS IN BINOCULAR VISION[1]

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The stereoscope, as ordinarily arranged, presents at the same time to each eye an appropriate picture. In a special form, devised by Prof. Münsterberg, however, the pictures are not presented simultaneously, but each eye sees its own picture for an instant while the other eye's picture is covered.[2] Still earlier, Dvorák showed that stereoscopic vision was possible under circumstances similar to these, and described certain illusions depending on that fact,[3] Dvorák, and later Exner, studied also the least time interval that could be observed between visual stimuli offered separately to the two eyes.[4] The study now to be described belongs to this general group, but the particular questions with which it deals are slightly different from any of these. The first problem undertaken was that of determining what time interval, if any, may be inserted between the presentation of each picture to its proper eye without marked interference with the perception of stereoscopic relief; and the preliminary results to be stated have to do chiefly with what is to be observed when the interval is made so long that stereoscopic vision becomes difficult or impossible.

The Apparatus. The apparatus used was in general terms, a Wheatstone stereoscope, fitted with notched disks in such a way that one eye's picture was first exhibited automatically

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[1] In view of the fact that Mr. Stevenson is no longer working in the laboratory and that the problem is about to be taken up by other hands, it has seemed best to make this report of results which seem to be demonstrated.

[2] Münsterberg: *Psy. Rev.*, I, 1894, 56-60, Studies from the Harvard Psychological Laboratory—a Stereoscope without Mirrors or Prisms.

[3] Mach: Analyse der Empfindungen, 1903, p. 196. Dvorák: Ueber Analoga der persönlichen Differenz, Sitz.-ber. k. böhm. Ges. d. Wiss. (math.-nat. Classe, März 8, 1872).

[4] Exner: Experimentelle Untersuchung der einfachsten psychischen Processe. Pflüger's Archiv, XI, 1875, 402 f.
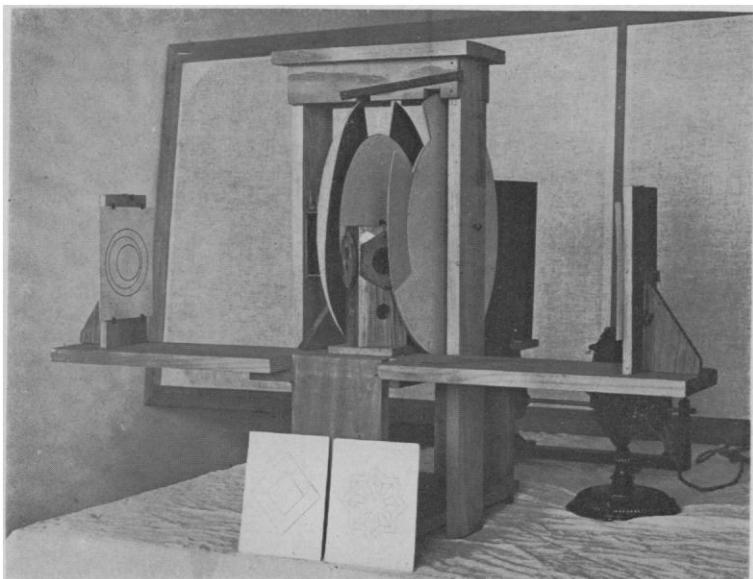
PLATE I
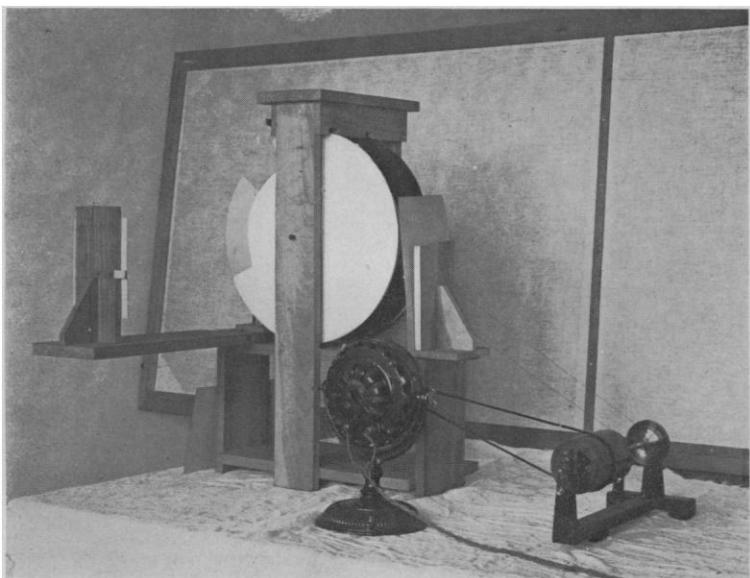
PLATE II

for a brief time, and then, after a known time interval, the other eye's picture was similarly exhibited for a time equal to the exhibition of the first eye's picture. The details of the arrangement will be made sufficiently clear by the accompanying plates and plans.
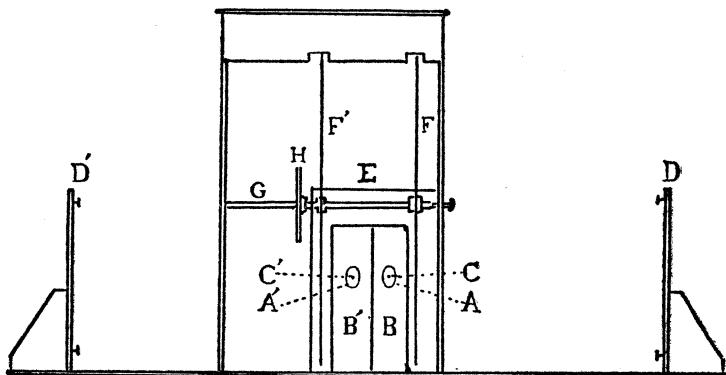
FIG. I
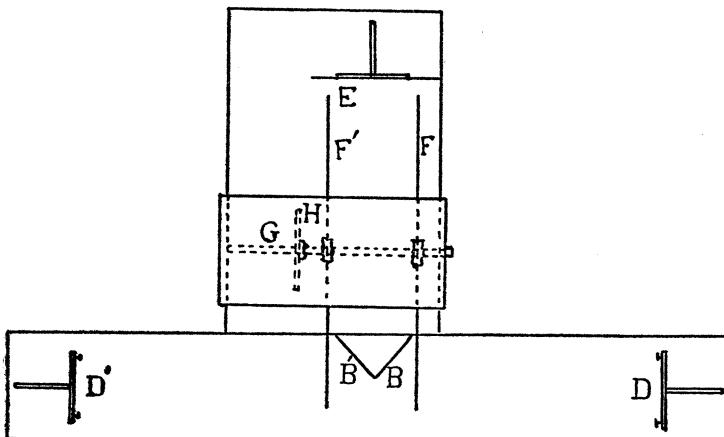
FIG. II

Plate I shows the apparatus as viewed from in front; Plate II, the same viewed from the side. Fig. I is a front elevation of the apparatus, and Fig. II its ground plan. *A'* and *A* in Fig. I are two plane mirrors, each about an inch and one-half in diameter, fastened over corresponding holes in two upright

panels, B' and B, standing at right angles to each other (Figs. I and II). In order to secure easy and perfect fixation, the silvering of each mirror was removed from a little spot at the centre, through which the observer looked at a white fixation point on the black background, E, which was itself carefully set so as to lie in a definite plane of the stereoscopic solid. Into coincidence with the fixation point just mentioned were also brought certain symmetrical points of the reflected images of the diagrams, carried by the panels, D' and D—usually the centre points of the larger circle or polygon.

The rotating disks used to secure the separate presentations of the diagrams are indicated by F' and F (Figs. I and II). These disks were 16 inches in diameter, and stood 4.5 inches apart. In the edge of each was cut a square notch, 30° wide and 2.5 inches deep. The disks were carried by a horizontal axis, G, lying parallel to a line joining the centres of rotation of the eyes of the observer, and 6.5 inches behind the centre of the mirrors. On this axis they were held by nuts which allowed them to be moved stiffly with reference to each other, and made it possible to set the notches in them quickly at any angular distance from each other up to 150° (180° minus 30°). The precision of the setting of the disks was tested by means of a straight edge attached to the frame of the apparatus, and a scale of degrees marked off on one of the disks.

The disks were rotated by an ordinary fan-motor, actuated by the commercial alternating current of the city, working through a series of pulleys to reduce the speed. The final pulley upon the axis of the disks is shown at H in the figures. This pulley was connected with the rest of the driving apparatus by a loose belt, running over an idle pulley serving also as a belt tightener. By this means the disks could be stopped or started as often as necessary without interrupting the movement of the rest of the driving apparatus. The rate of such a motor is usually quite constant, and in this case was tested before and after each experimental sitting (except one) by three timings of one hundred revolutions of the disks, each taken with a stop watch reading to one-fifth of a second.[1] The average rate found was slightly over 80 seconds per hundred turns. The greatest variation found in any single group of three countings was 0.4 seconds, and the extreme variation between timings taken in different days was 3.2 seconds. More exactly, the average time for one rotation of the disk was 0.804 seconds,

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[1] On one or two occasions during the experiments, the motor clearly slowed up for a few seconds at a time, because of a temporary interruption of the current, or for some similar cause. At such times observations were, of course, suspended until the normal speed was resumed.

and thus for one degree 2.23σ; for 10°, 22.3σ; for 20°, 45σ; for 30°, 67σ; for 60°, 134σ; for 90°, 201σ, and for 150°, 335σ.

In most of the experiments here to be considered, the right hand picture of the pair was shown first, except of course for the setting at 150°, when the pictures simply alternated at intervals of 335σ measured from the end of the period of visibility of one to the beginning of that of the next. The exposure time for each picture was constant at 67σ seconds (30°) or in common fractions, about 1-15 of a second.

One each of the three pairs of stereoscopic diagrams used is to be seen in Plate I. The one in the holder at the left and the right hand one of those in front of the instrument (designated in the notes as Diagrams 13 and 15) are familiar forms. The inner and middle circle of Diagram 13, however, were colored; the inner one red, the next violet, while the outermost was black. This difference in color was unnecessary and a disadvantage, as it possibly tended to suggest monocular relief in ways which would not have been present with figures all in black. Diagram 15 was drawn entirely in black, but was unsatisfactory for another reason; its oblique lines introduced definite tendencies to monocular relief, according as one or another of them was fixated, and these monocular tendencies sometimes co-operated with and sometimes opposed the binocular relief. The other figure (known in the notes as Diagram 14 and shown in Figure III) is a less common one, copied from
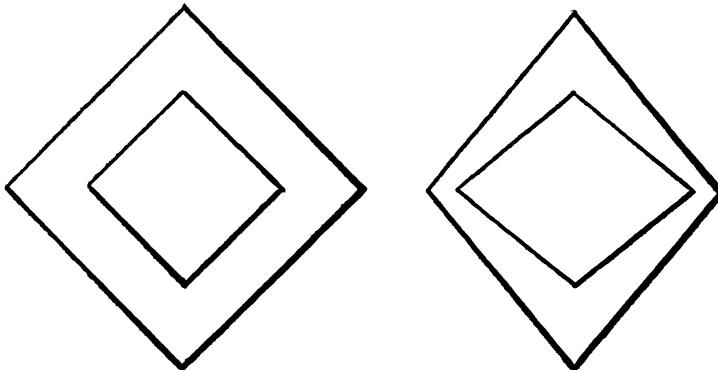

FIG. III

a collection of figures belonging to the Clark Laboratory. To those unfamiliar with it, this figure does not usually suggest, when uncombined, the form brought out by combination. When examined stereoscopically the diagrams show two diamond shaped planes intersecting at an angle of nearly 90°.

Reversal of any of these diagrams in the holders, of course,

brings about reversal in the apparent relief. It was easy, therefore, with a little care to begin a test without the observer's knowing what kind of relief he was to expect, and this was the usual procedure.

Of the large disks three sorts were used; one of black cardboard, one of white (the back of the black disks in this case, which gave a fair, but not exceptionally intense white), and one of a medium gray. These differences in brightness are by no means unimportant, for the disks not only shut off the vision of the pictures after the required interval of exposure, but the light which they reflect furnishes a general stimulation of the retina which has a profound effect upon the duration of the after-images of the diagrams. The illumination was ordinary day-light and, on several of the days, when it was necessary to experiment, varied considerably.

Method. The experimental procedure in the case of the more systematic experiments was as follows: A pair of the diagrams was adjusted in the holders and covered up to prevent the observer from knowing what form of relief to expect. The disks were then set with their notches at a considerable angular distance (usually 60°, though sometimes 90° or 150° was chosen), and put in motion. The observer took his place at the instrument, looked at the background and reported what he was able to observe. The experimenter, meanwhile, recorded the observations, asking questions when necessary to make the record definite. The observer was allowed to adjust his head and to use his eyes in the way most convenient to him. Occasional differences, due to fixation and movement, were reported. After observations with a large interval, the smaller were used in regular sequence: 30°, 20°, 10°, 0°, and —30°. The numbering of the scale of degrees was arranged to show the interval between the ending of the exhibition of the first picture and the beginning of that of the second. Zero degrees, therefore, means that one exhibition began the instant the other ended, and —30° means that the exhibition of both began at the same instant—that they were strictly simultaneous.

When observations had been made upon one pair of diagrams at the standard intervals, another pair was substituted and the process repeated. Similarly, when all the diagrams had been worked through with one pair of disks, another pair of disks was placed upon the axis, and the observation of all the diagrams at all intervals was again undertaken. The matters to which observation was especially directed were the nature of the stereoscopic relief, the apparent movement of the figures, and the character of the after-images.

Of the two chief observers, one (S) has had quite a little experience with work of this kind. The other (T) has had

only a small amount of general training in the psychological laboratory. A third observer (P) was, like the first, experienced in psychological experimentation. The note books contain one full set of observations for S and T with all the disks and all the diagrams, besides the records of some incidental testing taken while the apparatus was being perfected and at odd times during the taking of the regular set. For P, the records were taken with all the diagrams, but part with the gray and part with the white disks.

Results. The small number of systematic experiments and the complexity of the phenomena involved preclude our making any quantitative answer to our first problem, except a negative one. It is qualitative statements chiefly that we can make, and these for the most part with reference to what happens when the interval between the exhibitions of the two pictures is so long as to make stereoscopic vision difficult or impossible.

Our experiments have led us, however, to the conviction that *practically no interval whatever can be inserted between the periods of excitation of the two retinas* (including the duration of the after-image as a part of the first excitation) without destruction of the stereoscopic relief. It seems likely, on the contrary, that stereoscopic vision depends strictly upon the simultaneous excitation of the two halves of the visual apparatus.[1] Further systematic experimentation on this point may show that a very minute interval can be inserted, but it will certainly prove small even in comparison with the duration of the positive after-image.

Upon the following points, however, our observations have been so uniform and consistent that we feel justified in making a definite report with regard to them.

1. When the interval between the pictures is great enough to interfere with the usual stereoscopic apprehension of the diagrams, *their parts are apperceived as in motion.* They seem to change quickly from the position they occupy in one eye's diagram to that which they occupy in the other. This is especially true of the parts that fall upon non-corresponding retinal points, but it is also true to a certain extent of the parts that fall upon corresponding points, perhaps as a result of the relative way in which movement is usually perceived. Double images in the ordinary sense are not seen at such times and indeed cannot be seen until the periods of retinal excitation overlap and are thus, in part at least, simultaneous.

For Diagrams 13 and 15 this movement was chiefly a change

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[1] In Prof. Münsterberg's instrument, the positive after-images probably outlasted the entire interval.

of place, a sudden sliding or leaping from side to side of the inner parts of the figure, the diagrams having been so adjusted as to bring the outer parts approximately upon corresponding points. This movement was not always strictly horizontal but at times in an oblique direction, though there was nothing in the position of the diagrams or the observer that would easily suggest a reason. In Diagram 14 the movement was an apparent change in the shape of the figure itself, diamond to square or *vice versa*. This movement of the parts of the diagram was most striking with the longer intervals, and gradually decreased as the intervals were taken shorter and shorter, until it finally disappeared when the setting reached 0° or —30°. In some cases, the movement was apperceived as an excentric rotation in the plane of the background instead of a leaping from side to side; and in a few cases, when the interval was short, the movement seemed to be to and from the observer in the third dimension, instead of simply from side to side. In most cases, however, the movement and the binocular relief seemed reciprocal phenomena, the one decreasing as the other increases. When the conditions are not present for the adequate perception of relief, the apperceptive process takes on automatically another form, the perception of movement. In rare cases they are partially combined.

2. *As the interval is shortened and the conditions become more favorable to the apprehension of stereoscopic relief, the relief seems not to come in suddenly in full amount, but gradually.* Let us say, for example, that, in Diagram 14 the relations are such that under the conditions of ordinary stereoscopy the right hand point of the inner diamond would appear two inches in front of the right hand point of the outer diamond. Then with the gradually decreasing intervals of our experiment it would appear at first, perhaps, only half an inch in front and would gradually draw forward as the time between the pictures lessened until with the 0° or —30° settings it would be seen at full two inches in front. A corresponding but opposite change in the amount of the relief was to be observed when the interval between presentations was gradually lengthened from simultaneity.[1]

The gradual alteration of the amount of stereoscopic relief

[1] It may be noted also in passing that it was usually the *advance* of some part of the figure from the plane of the fixation point *toward* the observer that was first and most easily to be observed. The location of the portions back of that plane seemed more difficult and was slower in coming to observation. A similar relation was demonstrated to one of us by Dr. J. Carleton Bell, in the Wellesley Laboratory, some weeks before our experiments began. We note in passing this confirmation of a result already obtained by him.

just mentioned, seems to us of some theoretic interest and so far as it goes to furnish an argument in favor of the theory that the perception of stereoscopic relief is due to a reflex tendency of the eyes to move so as to fixate the different portions of an object seen in relief (a tendency not by any means perceived as such, but simply in its result, the binocular relief), and especially to support Wundt's account of the nature of the complex local signs in binocular vision. If the matter were a reflex one, we might very well suppose that the degree of binocular central excitation, and accordingly of the tendency to movement, would be roughly proportional to the time during which a very brief stimulus was operative binocularly, and such a proportionality our experiments seem to indicate.

It may perhaps be suggested that this increase in stereoscopic relief with shortening time intervals was due, not to the particular reflex relations above mentioned, but to a general improvement of the conditions necessary for an apperception of a third dimensional kind. In other words that the relief seemed to grow greater as it actually grew clearer. We are not inclined to think that this is the real explanation, though of course the matter must await further explanation.

One other point has been emphasized in our own minds by these results and that is the rather misleading way in which binocular vision is often presented in the text-books. The subject is a complex one and much allowance is to be made, but still it is customary to talk of binocular vision as though it were due to an actual psycho-physical fusion of two simultaneously present but independent monocular images; whereas, it certainly should be regarded as the physiological result of a certain balance or distribution of excitations in a symmetrically constructed but unitary visual apparatus.